AREAL RAINFALL ESTIMATES

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To obtain the most accurate estimate of the average rainfall on a given area, probably the best practice is to draw isohyetal lines and planimeter the areas under successive isohyetals. Judgment and personal equation, however, play a part in the drawing of these lines of equal rainfall, so that no two estimators get exactly the same results.

Since personal equation enters into the drawing of isohyetal lines, and since the time involved in drawing up and planimetering a long series of rainfall maps is considerable, it is evidently of benefit if a constant weight due to its location with respect to the drainage area and to other rainfall stations, can be applied to each rainfall station, which weight is of such a value that the resulting computations will give practically the same average rainfall, as would be obtained by the longer contour drawing and planimetering method.

In other words, if a weight can be given to each rainfall station as is done in the Thiessen method, but which takes into consideration the assumption of a straight-line variation of rainfall between stations, results will be obtained with the comparative ease of the Thiessen method and the accuracy that is obtained by drawing up a complete series of rainfall contour maps. The Thiessen method is explained by Robert E. Horton in the Engineering News Record for August 2, 1917, volume 79, page 211. Mr. Horton also describes the inclined-plane method for substituting missing data at rainfall stations. Continuing his line of reasoning, one arrives at the inclined plane or straight-line contour method of obtaining areal rainfall estimates.[1]

Briefly, the Thiessen method applies the rainfall at a station to all parts of the drainage area that are nearer to that station than to any other station. The drainage area is divided by first connecting stations by straight lines, then drawing perpendiculars at the center points of these connecting lines.

Figure 1 is a map of the drainage area of the Black River above Neillsville and Hatfield, Wis. Lines are drawn showing the division of the area according to the Thiessen method, and stations are also connected to form triangles which are the basis of the inclined-plane method. Three points determine each plane, and isohyetals in this case are made up of straight lines. Isohyetals are not actually made up of straight lines, but such planes and straight lines will produce a good average value for areal rainfall estimates. If the precipitation at one rainfall station is higher than that at surrounding stations, the average rainfall on an area near the first station will not be as large, when determined by straight-line contours, as by curved contours as usually drawn, but such a distinction is in most cases finer than the reliability of the original data warrants.

Questions will come up as to the formation of the triangle framework. Stanley and Marshfield are joined, since the distance between the two is slightly less than the distance between Medford and Neillsville. If thought necessary, both lines can be drawn, and the average effect of the four stations determined on the sum of areas 4 and 5. It appears difficult to reproduce contours to correspond to this average effect of the four stations in question, but average rainfall rather than contours is the object sought.

If we join Medford and Neillsville, straight-line variation of rainfall is better obtained through the drainage area than if the area is cut by a line between Stanley and Marshfield. It may be logically claimed that stations within a drainage area should be given more weight than

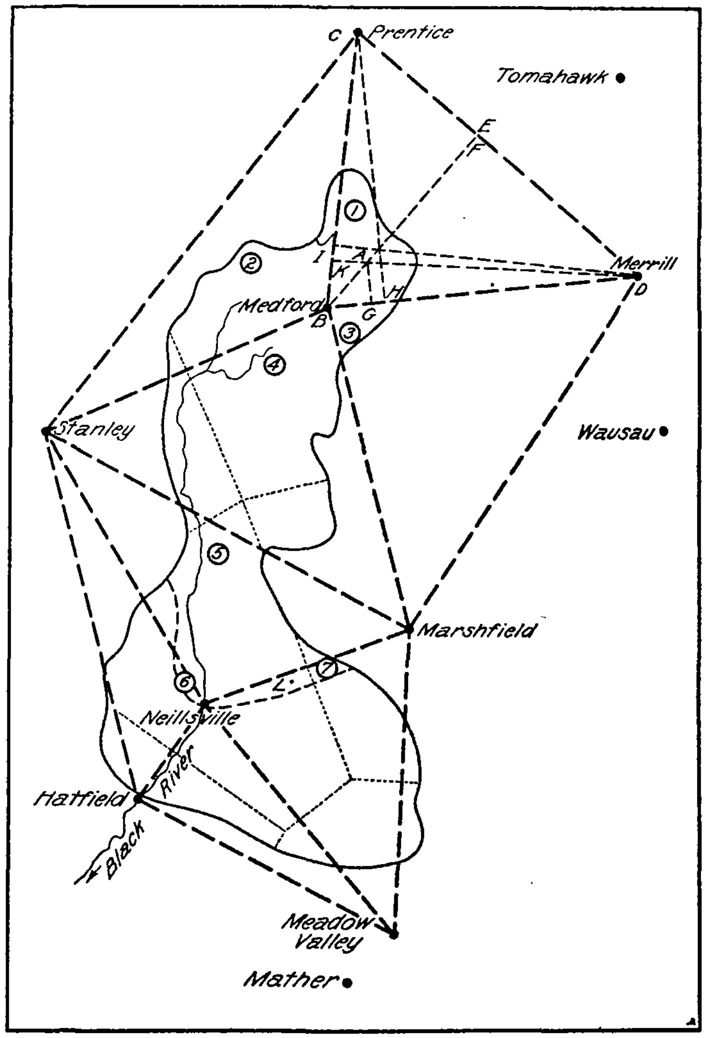

FIGURE 1.—Drainage area of the Black River above Neillsville and Hatfield, Wis.

stations outside of the area, but the simplest rule is to join by straight lines stations that are closer together than any other two stations.

It is probable that a strong triangle network should be sought giving triangles nearest to equilateral triangles in shape. Thus, it seems best to form triangles by connecting Neillsville with Meadow Valley, rather than by joining Hatfield with Marshfield, even if this second line is shorter than the first.

[1] See also the article by Robert E. Horton in MONTHLY WEATHER REVIEW, for June 1923, p. 296.

The objection to the Thiessen method is partly due to the ignoring of some stations outside of the drainage area. These outside stations are indicative of conditions to a certain extent and would be used if isohyetal lines were drawn. The inclined-plane method gives outside stations the weight to which they are entitled.

The drainage area above Neillsville is divided into seven parts by the triangles used in the inclined-plane method. The centers of gravity of each part are located by inspection or by any suitable method. The effect of the three surrounding stations is then determined on each center of gravity. If a triangle were entirely included within a drainage area, the effect of each of the three corner stations on the center of gravity of the triangle would be one third. On the drainage area above Neillsville this condition is not found.

On area No. 1, the center of gravity is at point A. The effect of Medford on point A and therefore on area No. 1 is proportional to the distance AE over the distance BF, or 0.74. The effect of Prentice equals AG over CH, or 0.14. Similarly the effect of Merrill is AI over DJ, or 0.12. The sum of these three constants is of course equal to 1.0. Instead of drawing the lines AI, DJ, etc., perpendicular to the sides of the triangle, lines may be drawn from each rainfall station straight through the center of gravity, A, to the opposite side of the triangle. The effect for Merrill on area No. 1 then becomes AK over DK, which is equal to AI over DJ.

Area No. 1 is 0.10 of the entire drainage area above Neillsville. The effect of Medford on the whole area as far as area No. 1 is concerned is 0.10 of 0.74, or 0.074. Similarly, the effect of Prentice is 0.014 and of Merrill is 0.012.

In the same way, figuring for each of the seven parts of the drainage area, the effects of each station are summed up to give the final constant for that station. The sum of the products of the rainfall at a station times its respective constant gives the average rainfall on the total drainage area. For small subdivisions of the drainage area such as 3, 6, and 7 the Thiessen method or a combination of the Thiessen and inclined-plane methods may be used. For area 3, Medford rainfall may be applied to all of area 3. For area 7, the effect of Meadow Valley may be ignored, and weight given only to Neillsville and Marshfield, in inverse ratio to their distances from the center of gravity of area 7 at point L.

Table 1 gives the constants obtained by the Thiessen method and by the inclined-plane method for the drainage area above Neillsville.

TABLE 1.—*Constants for areal rainfall estimates*

Rainfall station	Thiessen method	Inclined-plane method: With line joining Stanley and Marshfield	With line joining Medford and Neillsville	Average using both lines
Medford	0.571	0.369	0.522	0.447
Prentice	0	.041	.041	.041
Merrill	0	.012	.012	.012
Stanley	.104	.247	.113	.180
Marshfield	.070	.201	.050	.120
Neillsville	.255	.130	.262	.200
Hatfield	0	0	0	0
Meadow Valley	0	0	0	0
	1.000	1.000	1.000	1.000

This table shows that the effect of Prentice and Merrill is small, and that the effects of other stations differ considerably in the two methods. This difference may not alter the average rainfall greatly where annual rainfalls are used at the stations, but if monthly precipitation is used, which has a greater percentage of difference between stations, the average rainfalls obtained will differ to a greater degree than in the case of annual rainfall.

Annual rainfall run-off points were plotted for the drainage areas above Neillsville and above Hatfield on the Black River for the years 1915 to 1928, inclusive. Where the inclined-plane method of estimating the average rainfall on the drainage areas was used, improvement in the location of rainfall run-off points was shown. Apparently excessively high average rainfalls obtained by the Thiessen method were reduced when the inclined-plane method was used. In like manner, low average rainfalls were raised when the inclined plane method was applied.

The objection to the Thiessen method seems to be that we know that rainfall is not distributed uniformly over certain areas as the method assumes. We also know that average rainfall on an area is not perfectly described in terms of triangular planes, but we have more difficulty in proving how the rainfall distribution varies from this last assumption.

Other factors of course enter into rainfall distribution and amount such as altitude and direction of winds, but an alternation of the constants to allow for these conditions can be made if the estimator believes that he can make an improvement. If he obtains his original constants by methods that are the most logical, he will then have a solid foundation on which to base his later work.